Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

Gum Diseases of Citrus

IN CALIFORNIA

L. J. KLOTZ
E. C. CALAVAN

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CALIFORNIA CITRUS TREES

are attacked by a number of diseases in which the formation of gum on the trunks or branches is a conspicuous symptom. These diseases are grouped under the general classification of gummosis, but their outward appearances and ultimate effects on the trees differ.

The cause of some forms of gummosis is not known.

For most forms, effective methods of treatment are known.

In most cases, protective measures can be taken to guard against the danger of infection.

Basic preventive measures include:

- Keeping excess moisture from contact with trunks and crowns for extended periods.
- Keeping manure and other organic matter away from the bases of the trees and out of the planting hole.
- Spraying or fumigating only when conditions are favorable.
- Making periodical inspections of the trees to detect infection before too much damage is done.

THIS CIRCULAR

is designed to help growers recognize the various types of gummosis and to prevent or combat them.

Many of the points discussed here have been touched on in other publications listed on page 24. But the material included here is, as far as known, the latest information available.

The material on *Phytophthora* gummosis in the original edition referred only to the effects of *P. citrophthora,* the species commonly causing brown rot of fruit and gummosis of bark. The current use of rootstocks such as citranges and other hybrids has brought to light the increasing importance of other species of *Phytophthora,* particularly *P. parasitica.*

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The Authors:

L. J. Klotz is Professor of Plant Pathology and Plant Pathologist Emeritus, Riverside. E. C. Calavan is Professor of Plant Pathology, and Plant Pathologist in the Citrus Research Center and Agricultural Experiment Station, Riverside.

GUM DISEASES OF CITRUS IN CALIFORNIA

Any gum disease in a citrus orchard is important when it threatens the useful life of the trees. The greatest amount of space in this circular has been devoted to brown rot gummosis because it is the most destructive of the gum diseases, and because much is known about its cause and treatment—but it is realized that other gum diseases are not unimportant, and they should not be neglected.

With this in mind, the various gum diseases are here discussed individually, together with their causes, symptoms, prevention, and known treatments.

BROWN ROT GUMMOSIS OR FOOT ROT

Because both brown rot gummosis and foot rot are caused by the same fungi and require the same preventive and curative treatments, they are now considered to be different forms of the same disease. They are discussed together here.

During the wet years of 1938, 1941 and 1943 it is estimated that 900,000 cases of this disease developed in California citrus orchards. The disease is fatal to trees if they are not treated.

The cause of brown rot gummosis and foot rot is infection of the tree by one or more species of the *Phytophthora* fungi. These fungi attack the trees in different places, above and below ground, and bring about several types of injury.

The several species of brown rot fungi can attack leaves, blossoms, and fruit; one species is particularly destructive to fruit and foliage because its spore cases become detached and distributed throughout the tree by wind and wind-driven rain. Two species invade and destroy the bark of the trunk and rootstock. The infection may girdle the tree and eventually kill it.

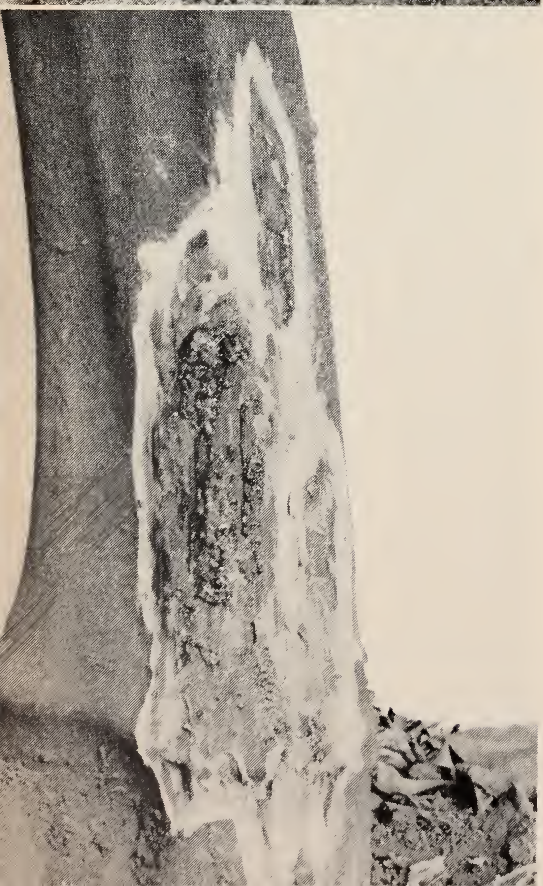
The indirect cause of these diseases may be one or more cultural practices or conditions in the orchard that favor growth and multiplication of the fungi. These conditions are:

- Having water in contact with the trunk and crown for as short a time as 5 hours. This may be due to flooding with irrigation water, or to heavy soils which do not drain readily.
- Injuries to lower trunk made by cultivation tools.
- Manure and other organic material piled against the trunk.
- Temperatures near the optimum for the growth of the fungi; 78°F for *P. citrophthora* and 89° for *P. parasitica*, the two most important species causing gummosis.

Obviously, the cultural practices favorable to gummosis should be avoided.

The symptoms of brown rot gummosis are varied, depending on where the tree is attacked.

In established trees the first and most evident symptom seen is a profuse gumming on the surface of the affected bark. From infections originating below ground in the so-called foot rot form, this gum is absorbed by the soil. The infection soon extends above ground, however, producing the typical masses of gum which exude and may harden in long, vertical ridges on the surface of the bark,



or run down onto the soil, as is shown in the photograph on the left.

Brown rot gummosis can usually be distinguished from other forms of fungus infections by the severity of the gumming, and by the fact that the affected bark is firm and will not yield to pressure by the fingers. Above ground this bark, even though it is killed entirely through to the wood, will remain firm until it dries out and cracks in vertical, flint-like strips infiltrated with hardened gum.

When scraped, affected parts appear darker than the surrounding green tissue. Removal of the bark will reveal a dark brown staining on the cambial surface (the soft, formative tissue between bark and wood). Usually this dark color marks the boundaries of the infection. Sometimes the infection in the outer bark will have extended beyond the boundaries of the discoloration on the cambial surface.

Beyond the region in the bark actually invaded by the fungus is a chamois-colored zone on the cambial surface in which a clear, watery gum is sometimes apparent. Since the causal fungus is not present in this zone, it should not be treated, even though it extends several times the length of the invaded (dark stained) zone.

Below ground, if the soil is moist, secondary organisms may cause a soft, malodorous decay of the bark, and a staining of the wood.

Twig injury, decay of fruit, blossoms and leaves during, or immediately following rainy, windy weather are also symptoms of infection by *Phytophthora* fungi. *P. citrophthora* does its greatest damage at temperatures near 78°F and *P. parasitica* near 89°F. Two other species, *P. hibernalis* and *P. syringae* are known to attack citrus in California. Their optimum

Here is a typical example of brown rot gummosis on a lemon trunk, before and after surgical treatment. This treatment is described on page 8 and consists of cutting out diseased bark and disinfecting the area in which fungi are present.

temperature for growth being near 63°F, they are active below ground and during cool weather.

In nursery trees and young orchard trees, symptoms of brown rot gummosis are usually found on the lower trunk and rootstock and just below or above ground level. Gumming and staining of the bark and wood (as described on old orchard trees) indicate probable gummosis infection.

Combative measures include preventive and curative treatments for both old and new plantings. Preventing the disease in established plantings consists in avoiding the orchard conditions, listed above, that favor growth of the fungi.

Prevention in new plantings, or in replacement plantings, may start with choice of a stock relatively resistant to the disease and not susceptible to other fatal diseases such as quick decline.

While resistance to gummosis is important in selection of a stock, it is not the *only* consideration. For instance: sweet orange on sour orange stock is highly resistant to gummosis, but very susceptible to quick decline (tristeza).

Other stocks relatively resistant to gummosis may not be suitable from a cultural standpoint, due to the climate or soil in a given locality.

It is therefore recommended that the stock be chosen for its suitability from a cultural standpoint as a prime consideration, and that its susceptibility to gummosis be considered secondarily (6).* Even though a stock is very susceptible to gummosis, by using the precautions recommended in this circular it can be successfully protected against the disease.

Work at the Experiment Station has resulted in a tabulation of citrus tree stocks, arranged according to their mean resistance as groups to brown rot gummosis. The table is shown on page 6.

Thirty-two selections of trifoliate orange and their hybrids (citranges and citremon) tested by planting in soil heavily infested with *P. parasitica* and *P. citrophthora* escaped gummosis (32, 33, 35). *Citrus taiwanica* (nansho daidai) and siamelo also escaped gummosis. However, when artificially inoculated by placing the fungi under the bark onto the cambium, all in varying degrees were found susceptible. The Texas, Japanese tetraploid, Davis B, English and Rubidoux selections of trifoliate orange were the most resistant (least susceptible) of the 32 selections to artificial injection. The tests emphasize the importance of avoiding injuring the rootstocks during orchard operations such as cultivating, furrowing, and suckering. To avoid quick decline (a disease common to sweet orange varieties on sour orange stock), many growers are demanding tristeza-tolerant rootstocks for new and replacement plantings.

The following procedure is therefore recommended for those who wish to make new or replacement plantings of rootstocks less tolerant to *Phytophthora* spp. In fact, this procedure is recommended for *all* new and replacement plantings, regardless of the stock used.

The first step is examination of the lower trunk and rootstock. (For symptoms, see page 3.)

If trees come balled in burlap, a representative sample (10 per cent of the trees) should be carefully examined by exposing the lower trunk and rootstock. All trees showing infection should be rejected. For replacements in an old orchard, if more than 10 per cent are infected the entire lot should be rejected. For virgin soil sites, some growers would reject any lot of trees that showed any evidence of *Phytophthora* gummosis infection. It would be well to have an understanding with the nurseryman regarding replacement of trees that develop gummosis within 6 months

* Numbers in parentheses refer to literature citations on page 24.

Approximate integrated response to natural and artificial inoculation with *Phytophthora* spp.

Highly susceptible	Lemons *(Citrus limon)* Some citranges *(Poncirus trifoliata × C. sinensis)*, except Troyer and Carrizo
Susceptible—order of susceptibility, highest to lowest	Sweet orange *(C. sinensis)* Limes *(C. aurantifolia)* Sampson tangelo *(C. reticulata × C. paradisi)* Rough lemon Grapefruit *(C. paradisi)* Mandarins *(C. reticulata)* Troyer and Carrizo citranges Citremon Nansho daidai (*C. taiwanica*) Siamelo Most selections of trifoliate orange *(P. trifoliata)*, including U.S.D.A. and Pomeroy
Resistant	Ichang lemon 1219 *(C. ichangensis × C. grandis)* Alemow *(C. macrophylla)* Sour orange *(C. aurantium)* Texas, Barnes, English, Rubidoux, and Davis B trifoliates Kumquat (*Fortunella* spp.) Severinia *(S. buxifolia)*

after planting. It is safest to obtain trees only from nurseries that use the best methods for avoiding the disease. These should start with a seedbed free of the causal fungi, and heat-treated seed (10 minutes at 125°F in water thoroughly agitated).

Soil of seedbed, nursery, and orchard tree sites can be disinfested of *Phytophthora* spp. and nematodes. The 1968–1969 *Treatment Guide for California Citrus Crops* lists seven materials effective for soil fumigation against these organisms.

If contaminated, the entire seedbed and nursery area should be fumigated. As it would be too expensive to treat the whole orchard area, treatment of individual tree sites is suggested. Treatment of an area 8 feet in diameter around the site enables a young tree to become established and make a good growth before recontamination of the area. After that the tree, if given good cultural care, can make successful growth and production in presence of the fungi.

For disinfestation of total areas and individual tree sites, the table on page 7 gives dosages of usable materials, methods of application, and waiting periods required before planting to allow chemicals to dissipate and not injure the young tree.

A convenient and effective way to apply Vapam to a tree site is in a circular basin. The basin, which should be 8 feet in diameter and enclosing about 50 square feet of soil surface, is made by ridging soil taken from within and at the exterior of the basin area. A pint of Vapam (31 per cent active ingredient) is placed in a pail at the center of the basin and water added to the pail and allowed to overflow into the basin to a depth of 4 inches of the Vapam-water mixture. To retard recontamination of the treated sites, the entire basin surface may be dusted with a one-package spray-dried Bordeaux from time to time to maintain a blue color on the soil surface.

Before planting, young trees should be treated for protection against brown rot gummosis.

Balled trees should have the balls dusted with a one-package, spray-dried Bordeaux dust, or with a one-package, spray-dried zinc sulfate-copper sulfate-hydrated lime dust. Or if it is more convenient, the balls may be sprayed thoroughly with a 3-3-100 Bordeaux* mixture. The only choice between these protective measures is one of convenience.

Bare root trees may be cleaned of infection by the common brown rot fungus, *P. citrophthora,* before planting by immersion in hot water, because citrus nursery trees will tolerate higher temperatures than will this gummosis fungus (2). To do this, water must be at a fairly constant temperature throughout the entire operation. Rootstocks and the entire root systems may then be immersed in the water for any one temperature and corresponding time period as follows:

Water temperature	Immersion time
110° F	10 minutes
111° F	8 "
112° F	6 "

The temperature-time exposures shown will serve to kill *P. citrophthora.* One-year-old seedlings of Cleopatra mandarin, Sampson tangelo, Jochimsen grapefruit, rough lemon, Jameson sweet orange, standard sour orange, Rubidoux and Webber-Fawcett trifoliate orange, Troyer citrange, and Ichang pummelo heeled into soil for 2 weeks before treat-

* 3-3-100 Bordeaux mixture contains 3 pounds of blue vitriol or copper sulfate ($CuSO_4$–$5H_2O$) and 3 pounds of hydrated lime [$Ca(OH)_2$] in 100 gallons of water. Because of the danger of copper injury, a good quality and adequate amount of hydrated lime should be used in making homemade Bordeaux.

SOIL FUMIGATION FOR PHYTOPHTHORA ROOT ROT IN REPLANT AREAS

CHEMICALS	GALLONS PER ACRE ON:		METHOD OF APPLICATION	MONTHS BEFORE PLANTING	FOR 8-FT. DIAMETER TREE SITE—FL. OZ.	CROPS
	SANDY LOAM	HEAVIER SOILS				
D-D, Vidden D	150	260	Injected 12"–14"	6 to 12	42	All susceptible citrus to be planted in infested soils.
Telone	120	210	Injected 12"–14"	6 to 12	34	
Vapam	100	100	In water 4"–8" deep	1½	16	
Vorlex	70	140	Injected 12"–18"	4 to 8	22	
Methyl bromide (tarped)	200 lb.	400 lb.	Injected 7"–8", tarped	1	8 (avoir. oz.)	
Chloropicrin (tarped)	400 lb.	800 lb.	Injected 12", tarped	3	16 (avoir. oz.)	

D-D and Vidden D contain chlorinated C_3 hydrocarbons, including 1,3-dichloropropene and 1,2-dichloropropane.
Telone contains chlorinated C_3 hydrocarbons, including 1,3-dichloropropene.
Vapam contains 4 lb. per gallon of sodium n-methyl dithiocarbamate.
Vorlex contains 80% chlorinated C_3 hydrocarbons, including 1,3-dichloropropene and 20% methyl isothiocyanate.

ment tolerated an immersion of their roots in water at 118° F for 10 minutes without any apparent injury. Because of the importance of injury to roots by the citrus nematode, *Tylenchulus semipenetrans,* it should be mentioned here that while 118° F for 10 minutes will destroy this parasite, it will survive the above-tabulated exposures (2). Birchfield (4) in Florida found 122° F for 10 minutes necessary to kill the burrowing nematode, *Radopholus similis.* Unfortunately, this exposure would be very injurious to nursery trees or seedlings of some varieties and would also be ineffective against the thick-walled oöspores of *P. parasitica.*

To date in California the burrowing nematode has been found only on some ornamental plants (which were destroyed), and not on citrus.

Planting. Inoculation of the bark of large roots, and of the rootstock below the line of differentiation into stems, indicated that root bark is less susceptible than stem bark. It is therefore well to plant the trees high, so that the first side roots are just barely under the soil surface and the bud union 6 inches or more above ground level.

Just before the first irrigation, dust the trunk to a height of one foot with Bordeaux or zinc-copper-lime dust, or whitewash with the same materials stirred into enough water to make a suspension about the consistency of house paint.

If the dust is used, the treatment should be repeated every 4 months during the first year. Two applications of the liquid are sufficient.

Where conditions for infection are prevalent, the protective treatment should be continued through the second year, or until the trees have made sufficient growth that irrigation water may be kept away from the trunk.

Inspection. Trees in any orchard should be examined at least once a year. Remove the soil around the crown and down to the first lateral roots if infection above ground is evident. Care should be taken to make sure that no depressions are left into which water is likely to drain and stand. If it is necessary to leave a depression, a drainage outlet should be dug.

By following the above practice, it is possible to detect gummosis and other troubles in the early stages so that corrective measures can be taken.

Treatment. When gummosis is discovered in the crown or trunk of established trees, the diseased bark should be removed by cutting it away to a line extending 1/4 to 1/2 inch into the surrounding healthy bark (see photo, page 4). The margin of the diseased area may be located roughly by the origin of the gumming, and then more definitely by a light scraping with a knife or tree scraper.

The infected part, when scraped, appears darker than the surrounding green tissue. The inner, or cambial surface, of the diseased bark and wood is a dark reddish brown. The tan, or chamois-colored, bark beyond is not invaded by fungus and should not be removed or disturbed.

It is not necessary to scrape or cut the wood. By scraping the bark lightly to a line 1 to 2 inches beyond the area of invasion, the tendency to gum following the painting with Bordeaux is decreased.

The exposed wood should be disinfected with either a 1 per cent solution of potassium permanganate (1 teaspoonful of crystals to a pint of water) or with a paint made by mixing the powder of fresh one-package, spray-dried Bordeaux with water to about the consistency of house paint.

After application of the above treatment, when healing calluses begin to show at the edges of the bark, the wood should be painted with white lead or with a non-injurious asphalt emulsion.

If the diseased area is larger than a man's hand, or of long standing, a 2- to 3-inch strip may be removed from the margin toward the center of the affected bark, and the dead, dry center portion, which is difficult to remove, may be left because the causal fungus is killed out by the drying. If a small tree has a gummosis lesion involving half or more of the circumference it is better to replace the tree.

Twig invasions. The fungi causing brown rot gummosis sometimes invade the upper parts of the trees, causing twig injury or decay (or both) of fruit, blossoms and leaves. This type of infection may be prevented but not cured.

The most effective known method of prevention is to spray 1 to 3 weeks prior to, or just after, the first rain of the season with a 3-4½-100 Bordeaux mixture, or a 5-2-6 zinc-copper-lime mixture, or a reacted and spray-dried copper fungicide containing 0.6 to 0.8 pounds of copper (metallic) per 100 gallons.*

In some localities the application of copper sprays has aggravated leaf fall and caused pitting of leaves and fruit. For these reasons concentrations of Bordeaux and other copper sprays have been reduced to these dilute sprays, and sprays of non-copper materials sought as substitutes.† One of the more promising is Captan used at the rate of 2 pounds of the chemical (50 per cent active ingredient) per 100 gallons of water. Since this does not resist weathering as well as the copper sprays a second application should be made 10 to 12 weeks after the first (9, 30, 31).

Where there is no history of infection above the 4-foot level, spray the foliage and fruit to that height. In addition, the ground under the tree and the trunk should be sprayed.

Where infection has appeared in previous years above the 4-foot level (indicating that the aerial form of the fungus is present), or if correction of copper or zinc deficiency is desired, the entire tree and the ground under the tree should be thoroughly sprayed.

GUMMOSIS CAUSED BY OTHER FUNGI

Several other types of gummosis caused by fungi have been found in California and while they are not as important commercially as brown rot gummosis, it is advisable to know their symptoms and to guard against them.

Prevention and treatment consist in surgically removing all diseased bark and wood, and then disinfecting and covering the exposed healthy wood with white lead or tree seal.

The direct cause of these other types of gummosis is, of course, infection by fungi. The indirect cause may be:

- Damage to the trees by frost, sunburn, mechanical injury, oil sprays, fumigation, or the various chemicals used in sprays and fertilizers.
- Weakening of the trees' natural resistance by shell bark, viruses, nematodes, insects, mites, bud union incompatibilities, and phloem abnormalities.

The general symptoms are similar to those of brown rot gummosis, but the gummosis is usually less profuse and the extent and severity of the damage are usually less.

Invasion of bark by *Botrytis cinerea*

* Bordeaux mixture 3-4½-100 contains 3 pounds of powdered copper sulfate (pentahydrate) called bluestone; 4½ pounds of hydrated lime; in 100 gallons of water. Zinc-copper-lime, 5-2-6-100 contains 5 pounds of zinc sulfate (heptahydrate); 2 pounds of powdered bluestone; and 6 pounds of hydrated lime in 100 gallons of water. Zinc sulfate monohydrate may be used; 3 pounds are equivalent in zinc to 5 pounds of the heptahydrate.

† For areas where damage from copper sprays is severe (areas with air pollution, smog, sulfur oxides) either the zinc-copper-lime 5-2-6-100 or Captan 50W, 2 pounds in 100 gallons or equivalent in active ingredient, may be used. Captan residue on fruit must not exceed 100 ppm of the whole fruit. Do not feed citrus by-products treated with Captan to dairy animals or animals being finished for slaughter.

Here branches and twigs of a lemon tree have been invaded by Botrytis fungus, following injury by freezing. Both preventive and curative measures may be taken to combat this type of disease.

(gray mold) is detected by the presence of the gray-colored, velvety, fruiting heads of the fungus on the bark surface (see photo above). In the early, active stage, the bark is soft.

This disease may cause considerable damage to trees injured mechanically or by cold or by shell bark.

The cottony rot fungus, *Sclerotinia sclerotiorum*, may attack and kill all injured parts of the tree. As in *Botrytis* gummosis, affected bark is soft at first, but turns gray to almost white and breaks into shreds. Among the shreds of bark on the wood surface are black, irregular bodies of the resting stage of the fungus. Gumming may be rather profuse, but not as profuse as in brown rot gummosis.

Both *Botrytis* and *Sclerotinia* fungi cause twig blights that are similar in nature. Starting in the ends of twigs or in the blossoms they kill the twigs back for a few inches. Their progress is arrested, however, by warm, dry weather.

Diaporthe citri and *Diplodia* spp. attack bark weakened by shell bark disease, and also by the other factors mentioned above, causing a gummosis. They and *Botrytis* will also invade growth cracks, pressure ridges and wounds. These fungi are particularly severe when working together in shell bark areas, for they may kill the bark through to the cambium, and *Diplodia* may invade the wood. *Diplodia* advances in the wood of twigs and limbs injured by frost. Either *Diaporthe citri* or *Diplodia* spp. alone is able to invade the inner bark, and the former (*Phomopsis* stage), although usually confined to bark, can invade the wood of weak trees. The black spore-containing structures (tiny black spheres embedded in the bark) of the two fungi may be found on the affected parts.

Gummosis caused by *Diaporthe citri* or *Diplodia* spp. or mixtures of the two fungi are more important in Florida, South Africa, and some Mediterranean countries than in California.

Two bark diseases, *Diplodia* gummosis and *Dothiorella* gummosis (caused by the Dothiorella stage of *Botryosphaeria ribis*) are so much alike that it is difficult to distinguish one from the other. They attack the trunk, large limbs and crotch of trees that have been weakened by cold, age, or other agencies, and may destroy large areas of bark and kill large limbs or the entire tree. They may also attack the wood. However, on vigorous trees not severely damaged the lesions are often small and easily healed. They are characterized by the formation of elongated gum pockets in the inner bark, next to the wood surface.

On old, severely damaged lemon trees gum pockets may be absent. The affected inner bark is brown to black in color.

Combative measures. Keeping the danger from these fungus diseases at a minimum is important, and may usually be accomplished by taking the following steps:

- Avoid injury to the trees by cultivation tools and burrowing animals.
- Where possible, provide adequate orchard heating to prevent weakening of the trees by cold.
- When frost damage does occur, protect the exposed bark by whitewashing.
- Pruning citrus trees, especially lemons, provides better ventilation, stimulates growth, and is useful in limiting damage by these types of gummosis.
- Disinfect pruning cuts with 4 per cent formalin, or a safe carbolineum. Allow disinfectant to dry for 3 days, then cover with white lead paint or tree seal.
- Avoid applying oil sprays when the trees are too dry.
- Distribute fertilizer evenly over ground surface so it does not pile against trees.

In addition, paint or spray the trunks and crotches of the trees with fungicides such as Bordeaux, or zinc-copper-lime mixture (about the consistency of house paint), or with one of the new carbamate fungicides (½ per cent solution) to discourage the fungi.

Surgical treatment for any of the above fungus diseases is the same.

The invaded parts are cut away to a line ¼ to ½ inch beyond the margin of the lesions and the surface is painted with Bordeaux paste or with a noninjurious brand of carbolineum (i.e. carbolineum having a relatively low phenol content). Any carbolineum or asphalt paint should be tried out on small areas of bark in the sun and shade. If it roughens or kills the bark, it has too high a content of phenol.

Where the fungi have killed only the outer layers of bark, the bark should be removed by scraping with a tree scraper.

Wood invaded by *Diplodia* or *Dothiorella* should be removed and the cut surfaces disinfected with 4 per cent formalin or a safe carbolineum or Bordeaux paste. When the wounds are dry, either of these treatments should be followed by covering with a noninjurious asphalt paint.

A single application of a safe carbolineum, without a follow-up coat of asphalt paint, may also be used, but the exposed bark and wood should be whitewashed to prevent sunburning.

DRY ROOT ROT MAY BE CONFUSED WITH BROWN ROT GUMMOSIS

Recent examination of citrus trees in various stages of decline has revealed many with a disease called dry root rot (34). As first noticed by the grower, leaves have wilted suddenly and dried up in place (as in the collapse stage of quick decline), or some of the leaves have dropped, giving the tree an open, thin appearance with more dead twigs than usual. These symptoms are common to any trouble caused by an agent which kills roots or girdles the tree in whole or in part.

Further examination discloses that a portion or all of the bark at the crown of the tree shows first a moist decay which later dries, cracks and shreds. This may suggest gummosis; but lack of gumming together with a dusky to black discoloration of the wood below its surface, revealed by cutting, precludes gummosis as the main cause of the trouble. *Phytophthora* gummosis fungi do not invade citrus wood beneath the cambium layers.

Occasionally the affected part has a fishy odor. The appearance of the tree above ground depends upon the number of roots affected and the extent to which the wood of the crown is involved. In terminal cases the decaying wood becomes punky in texture.

All of the common rootstocks are susceptible, including trifoliate and Troyer citrange, which have considerable resistance to brown rot gummosis.

Develops from Injury. While all of the factors and sequence of disease development may not be evident, apparently damage to the root or crown tissue by one or more of several agencies opens the way for initiation of the disease. Suffocation of the fibrous feeder roots by overwatering; infection of the bark of feeder roots or larger roots or crown by gummosis fungi; or damage to the roots by strong inorganic or organic fertilizers or by herbicides, nematocides, tillage, kerosene sprays, gophers and other rodents may provide a starting place for dry root rot.

The initial damage to the tree may occur shortly after planting or at any period in its life, and may require several years before the trouble causes symptoms apparent in the above ground parts.

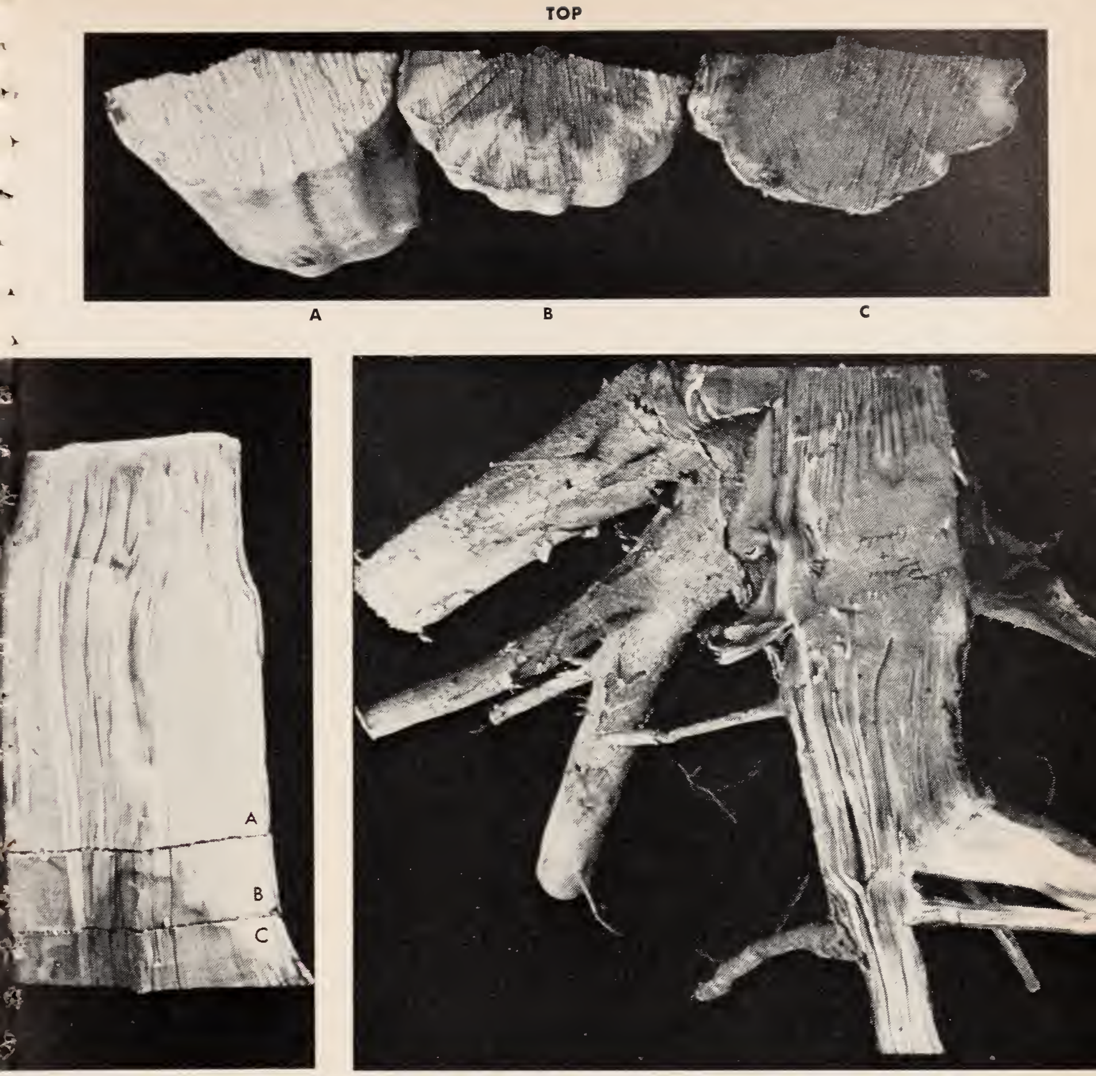
As revealed by cross and longitudinal sections (photos, page 13), dry root rot may start in a rotting fibrous feeder root or larger root and progress into the still larger roots and, ultimately, the crown of the tree. Or it may appear first at the crown if the injury occurs there. Also, staining and decay may work from the crown into the larger subtending roots.

Bark beyond the starting point of the disease remains intact until the wood cambium immediately beneath it becomes involved. Then the bark dies. In collapsed trees, most or all of the woody cylinder of the crown may be diseased.

Cultures from the affected wood generally yield one or more species of *Fusarium* and bacteria and occasionally low grade citrus parasites found in soils such as *Macrophomina* sp. or saprophytes such as *Chaetomium* sp. Eventually, other wood-destroying fungi enter and reduce the wood to punk. In microscopic sections of the wood, *Fusarium* spp. are seen to progress through the living cells of the medullary rays and into the soil solution-conducting vessels. Fortunately, in most cases of damage to the fibrous roots *Fusarium* spp., bacteria and other low grade parasites fail to become established and active in the wood.

Control. To decrease the incidence of dry root rot, avoid excessive watering; do not permit water to stand in contact with the tree crown. (If sprinklers are used, direct the water so as to minimize wetting of trunks). The precautions suggested to prevent and combat gummosis in young trees apply to dry root rot, for gummosis lesions favor the early development of the disease. Follow carefully the manufacturers' instructions for dosages and methods of application of herbicides, nematocides and other pesticides. Inspect regularly for gummosis and gopher activity and take prompt control measures.

Fertilizers applied in the hole around the roots or next to the trunk of young trees at the time of planting have at times



Left: Longitudinal section of Troyer Citrange showing progress of dry root rot from roots to crown. Top: Ends (cross sections) of areas A, B, C shown in photo on left. Right: Longitudinal section through crown and subtending roots of the Troyer rootstock, showing staining and decay caused by dry root rot.

caused severe injury (15). Wait at least 6 weeks, or until the young tree has put out new growth and becomes established before applying fertilizers.

In the advanced stages when fruit production no longer justifies keeping the tree, it should be removed and its site should be replanted.

RIO GRANDE GUMMOSIS

Rio Grande gummosis is the more common name for a disease that Godfrey (27, 28, 29) has called "infectious wood necrosis and gummosis" and which is considered one of the most serious citrus tree diseases in southern Texas. In California the disease—or a similar malady called "ferment gum disease"—has affected only grapefruit trees.

Not all the factors involved in the cause

Left: Rio Grande gummosis (ferment gum disease). Right: Artificial reproduction of the disease (from unpublished work of E. C. Calavan and J. M. Wallace). Photos by T. A. DeWolfe.

of Rio Grande gummosis are known, although certain microorganisms isolated from infected wood have reproduced some of the symptoms when inoculated into trunks and large limbs (8, 17, 40).

Symptoms. The disease apparently starts at injuries and pruning wounds. At the place of entrance and where the advancing band of infection approaches the wood surface and kills the cambium, the bark cracks and gum exudes profusely, and gum blisters form nearby.

The affected wood, which is dusky to tan or light brown in color, with a narrow orange-colored margin, occurs in a band often an inch or more below the surface, so that it may be necessary to chisel through unaffected wood to discover the stained tissue. The band of diseased wood usually ranges from $\frac{1}{4}$ to 4 inches in thickness, may be several inches wide, and may spread upward and downward 2 or more feet from the point of infection.

Avoid Rio Grande gummosis by protecting against freezing injury and by disinfecting and coating all pruning wounds and injuries made by ladders—the most likely places for infection to start.

Control measures recommended include pruning off severely affected branches and, where feasible, chiseling out affected wood in the trunk and larger limbs. Such surgery is impractical if wood involvement is extensive. According to Godfrey healthy, exposed wood resulting from this pruning or chiseling, or both, should be treated with a penetrating disinfectant, such as carbolineum, with 2 per cent phenol. He states that final coating on the excavations should be made with a material consisting of equal quantities of low melting point asphalt and carbolineum with 2 per cent phenol. It is extremely important that all of the disinfected wounds are covered—if not, there is danger that secondary, wood-destroying fungi will invade the affected areas and cause more trouble.

HENDERSONULA BRANCH WILT

Fawcett observed a fungus resembling *Torula dimidiata* (later named *Hendersonula toruloidea*) damaging frost-injured orange and grapefruit trees in Tulare County. Branches and parts of the trunk were killed, and large pockets of gum formed under the bark. Later, black, powdery spores of the fungus were produced under the epidermis of the dead bark. A. J. Olson (Fawcett, 20, 21) found the fungus attacking citrus trees following the 1931 freeze in northern California. Calavan and Wallace (12) produced a gumming by artificial inoculation with the fungus and stated it is sometimes present in Rio Grande gummosis. This disease occurs mostly in very hot, desert areas.

Control measures are described above, under "Rio Grande gummosis." All of the bark areas exposed to the sun in hot, inland locations should be whitewashed.

Below, Left: Tree with Hendersonula Branch Wilt. Center and right photos show Hendersonula infection of trunk (note black spores), and gum on branch.

MINOR FORMS OF GUMMING CAUSED BY FUNGI

Several fungi, including *Penicillium roseum*, which in coastal sections has at times been associated with *Botrytis* gummosis and shell bark; *Fusarium* spp. which are often associated with *Phytophthora* spp. in brown rot gummosis; *Alternaria* spp., and some of the wood-rotting fungi, such as *Schizophyllum commune*, are capable of inducing small amounts of gum. In California at the present time, the amount of bark injured or killed by these fungi is small.

VIRUS DISEASES

PSORSIS (Scaly bark)

Some virus diseases of citrus are accompanied by a formation of gum. Trees infected by the psorosis virus may gum profusely in the later stages of the disease. In the early or later stages before bark scaling is evident, psorosis is detectable by small, elongated clearings or flecks, from light green to yellow in color, lying along the small veinlets of young half grown leaves. The flecks vary in size from .04 to .12 inch in length and .02 to .04 inch in breadth. They may occur throughout the entire surface of the leaf blade or only in small areas. Sometimes the flecks form a pattern with a watermarklike outline similar to an oak leaf. This type is found accompanying concave gum disease.

These marks may be most readily seen by viewing in the shade, with light from the sky coming through the leaf. In

Left: Typical scaling bark lesions of psorosis which develop spontaneously on trees propagated from diseased parent trees. Right: The extensive development of a rampant form of psorosis which is shown in this photo resulted from experimental inoculation of a healthy tree with bark from a local psorosis lesion. Although this rampant form rarely occurs naturally, it is most destructive when it does.

Left: Orange leaf showing the typical flecking pattern denoting infection by psorosis. Center: Oak leaf pattern of clearing associated with concave gum disease (photo by J. M. Wallace). Right: Target-shaped markings on orange leaves in this photo are associated with the rampant type of psorosis.

choosing leaves to examine, make sure they are free from injuries, such as those caused by sand blast, hail, red spiders, thrips, aphids, leaf hoppers, etc. which might be mistaken for psorosis symptoms.

The symptoms of psorosis in leaves are usually evident long before bark, wood, or fruit symptoms appear. There are orange trees over 60 years old that still have only leaf symptoms.

Inasmuch as leprosis disease on Florida citrus is also called scaly bark in that state, it is advisable to avoid confusion by adopting the name psorosis for the dis-

Left to right: The typical symptoms of concave gum, blind pocket, and eruptive blind pocket diseases. These diseases are most commonly found in orange trees. There is no effective known treatment for any of these troubles, but they can be avoided by propagating with disease-free seed and budwood.

Left: Grapefruit leaves with the small, necrotic ring markings associated with the rampant form of psorosis. Right: This photo shows the misshapen fruit and the leaf symptoms (not the crinkling, flecking, and variegation) associated with infectious variegation.

eases which are described herein.

None of the virus infections can be cured permanently by present known methods. All of the diseases cause gradual deterioration of the trees until they are commercially useless. Steps can be taken, however, to avoid psorosis, and certain measures have been found that will prolong the useful lives of trees having psorosis.

The specific symptoms which will usually determine what type of virus infection has taken place are as follows:

Psorosis brings about scaling bark lesions on sweet orange, grapefruit, and tangerines, and stunting of some trees, notably lemon. (Photos, page 16, 17, and 18.)

This disease usually appears first on the older bark of the trunk or limbs of trees 12 or more years old and seldom on trees younger than 5 years. It is evidenced by small scales with or without gum formation, or as groups of pustules (blisters) under which are brown specks. The scales from the outer layers of bark are dry, irregular in shape and about 0.1 of an inch thick. The bark underneath them is living, and is tan to buff in color.

As the disease advances, the deeper layers of bark and wood become affected. The wood layers become infiltrated with gum and hard, resinlike materials, and later become stained a reddish brown. Such wood loses most of its function of conducting soil solution and the tree then deteriorates rapidly, showing sparse foliage and many dead twigs.

A severe and rampant form of psorosis is occasionally seen. It can be distinguished from the local, slowly spreading type by the fact that gumming appears first and precedes the scaling. Wallace (49) produced it experimentally by grafting a trunk or branch of a healthy tree with a bark patch taken at the edge of a psorosis lesion. This type advances very rapidly in continuous strips of gumming and scaling areas on the trunk and larger branches. Small branches and twigs are affected in the early development of the disease. In addition to the general leaf flecking, some leaves and fruit may show necrotic ring spots of varying sizes. Types of psorosis intermediate between this and the common types have been observed.

Combative measures. While psorosis can not be cured, it can be avoided by using buds only from trees that are known to be free of symptoms. Since the only known means of transmission of the psorosis diseases is by union of living tissue (budding and grafting) or by an occasional natural root grafting, there is no significant spread from tree to tree. However, the virus is known to be spread by seed of some citranges, and a psorosis-like virus in Argentina spreads naturally (19, 42, 43).

The Nursery Service of the California Department of Agriculture on request from growers and nurserymen, and for a fee, will examine trees for registration or certification as free from psorosis and certain other viruses. Budwood from such trees can be used to propagate healthy nursery trees (39, 45).

Branches severely affected should be pruned out. Bark lesions on the large limbs and trunk should be treated in the early stages.

Psorosis bark lesions should be treated in the early stages, when the lesions do not exceed the area of a man's hand.

One treatment consists of scraping the outer layers of bark over the affected part and also over the apparently healthy bark for a distance of 6 inches above and below, and 4 inches to sides around the lesions. Scrape to a depth sufficient to remove the discolored layers (¼ to ⅓ the thickness of the bark). See Fawcett (20, 21, 22, 23), and Klotz (30).

No disinfectant is needed after scraping if the treatments are made in the late spring and summer months when the bark recovers most rapidly. Bark scraped in the late fall or winter is subject to injury by low temperatures.

A chemical treatment for scaly bark (22, 23, 47) developed in 1944–46 was abandoned because its use necessitated extreme care to avoid injuring healthy bark, and because production of the chemical "dinitro" (dinitro-o-cyclohexylphenol) was stopped.

The rampant form of psorosis, concave gum, and blind pocket psorosis diseases cannot be treated economically by surgery or any other known method. When trees decline to the point where they are commercially useless, remove them.

The same is true for trees showing symptoms of crinkly leaf and infectious variegation.

Concave gum disease, blind pocket, crinkly leaf, and infectious variegation were once thought to be caused by strains of the psorosis virus because of the common occurrence of the flecking symptoms. Some investigators now think that those diseases are caused by virus entities distinct from psorosis, and that the flecks may be caused by concurrent infection with psorosis virus.

Concave gum disease is found on orange and mandarin trees. (Photo, page 17, bottom.) On trunk and limbs it produces relatively broad concavities—a result of the virus' retarding and at times arresting the formation and growth of wood in the affected parts. Bark covering these depressions is apparently normal, but may sometimes crack open and allow gum to ooze to the surface. Tissue on the surface layers of wood is gummy or granulated and reddish brown in color.

The underlying layers of wood are usually thinner than normal for the season's growth, and are impregnated with a substance semiliquid to gummy or cheesy in consistency. Affected layers of wood are thin and filled with gum, but some layers apparently normal in thickness and color may be found in the concavity. Young leaves seasonally show the oakleaf pattern of clearings.

Blind pocket disease of orange causes an abruptly narrow creasing in the surface of the trunk and limbs, giving a fluted effect (Photo, page 17, bottom). Some cases have less abrupt slopes and resemble those of concave gum disease. The concavities vary in size from a few inches to the entire length of the trunk. Tissue in the wood at the bottom of the crease is softer and less dense than normal, and is yellow to yellow-salmon in color. Eventually it is impregnated with a cheesy or gummy material.

Occasionally blind pocket disease will be accompanied by exudation of gum from the pockets, and by the formation of scales that are coarser and thicker than those found in psorosis.

Crinkly leaf psorosis disease of lemons causes no apparent injury to the bark or wood of the lemon tree. The only symptoms of the disease are the flecking (see right-hand photo, page 18) of the young leaves and a warping and pocketing of the leaves and distortion of the fruit on some branches.

Infectious variegation (photo, page 18) has all of the symptoms of crinkly leaf and, in addition, a leaf variegation caused by an irregular chlorosis (discoloration) of the leaf blade. Lemon fruits may be deformed and have dead areas in the rind. It causes distortion and variegation of sour orange leaves. It is rarely seen in the orchard (21).

EXOCORTIS

(Bark Shelling of Trifoliate Orange and its hybrids, and Rangpur Lime)

This is an important virus disease (3, 5, 6, 7, 18, 25, 50, 51) among orange trees on rootstocks of trifoliate orange its hybrids, and Rangpur lime. Some orchards of old trees have shown over 25 per cent infection with stunting of affected trees. Nearly all lemon trees, except those of seedling lines, are infected.

The bark symptoms resemble more nearly those of shell bark of lemon than those of scaly bark of orange and often appear at or below the soil surface. Narrow strips of the outer bark dry and separate from the inner live bark and slowly peel off as they weather. This is similar to the peeling of a shell bark hickory tree (Photo, top of page 21).

The bark strips are 1 to 5 inches long, ⅛ to 1 inch wide and $\frac{1}{10}$ to ⅛ inch thick. On the surface of the bark beneath the shelling bark a layer of hardened gum sometimes forms. Because of the general association and similarities of symptoms, Calavan and Weathers (13) "suggest that exocortis virus may possibly be an important causal factor in the development of shell bark on many lemon trees."

While trees on healthy trifoliate orange are often smaller than the same varieties on some other commercial rootstocks, the stunting is much greater when the tree has exocortis. The trunk diameter of two 23-year-old navel trees on shelling trifoliate in an experimental planting measures only half that of 20 other trees on unaffected trifoliate stocks. The volumes of the tops of the diseased trees were only ⅙ to ⅕ of those of the healthy trees.

It has been demonstrated that mechanically transmitted exocortis virus definitely stunts citrus and herbaceous hosts. On contaminated tools the virus retains its activity for long periods (1).

Combative measures. Exocortis cannot be cured but, assuming the absence of an insect vector, it is possible to avoid the disease by taking the following precautions:

- Avoid using budwood from trees on trifoliate which show evidence of the trouble. While there is no evidence at present that the disease is transmitted through seed, as a matter of precaution seed from affected trees should be avoided.
- Use budwood only from trees indexed and found free of virus and registered or certified as such. The long search for a satisfactory method of indexing exocortis (18, 38) led to the development of an excellent rapid test which employs the epinastic and stunting responses of certain selections of Etrog citron (USDCS 60–13 or Arizona 861) when budded into citrus harboring the virus of exocortis (11). Weathers *et al.* (51) found that *Gynura aurantiaca*, and *Petunia* spp., as well as several other herbaceous plants, exhibited pro-

Above: This is a closeup of a trifoliate orange root-stock, showing typical symptoms of bark shelling. This disease also results in stunting of trees.

nounced stunting and epinasty when inoculated with this virus.

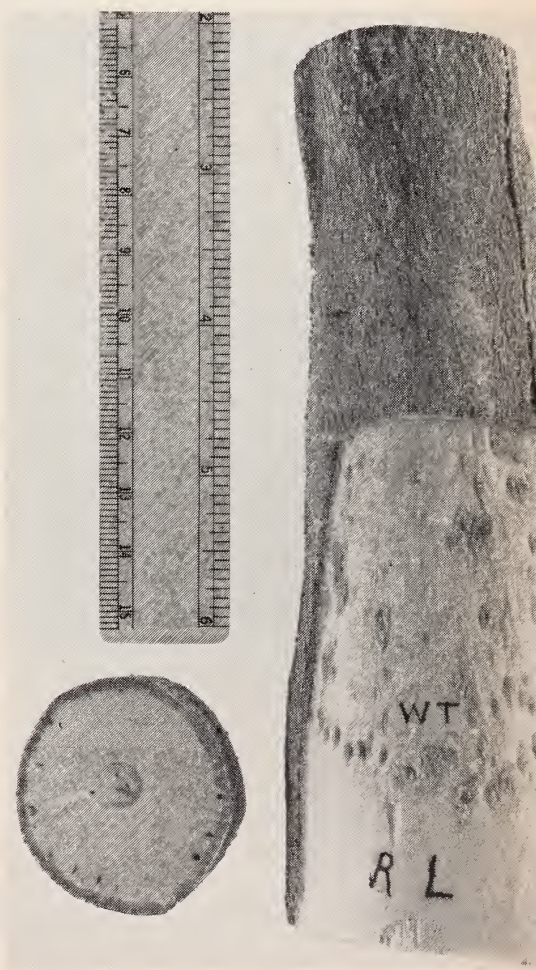
Garnsey and Jones (26) have shown that the virus of exocortis is readily transmitted to healthy plants on budding knives. They suggest decontaminating the tools by dipping them in a solution of 2% sodium hydroxide and 2% formaldehyde (active ingredient) in water. Roistacher *et al.* (46) found that dipping the knives in a 10 to 20% solution of household bleach (5.25% sodium hypochlorite in the concentrated bleach) is an effective sterilant. To retard corrosion of the steel by the chlorine they rinse the knives in a solution of 1 part vinegar, 2 parts water, and 2 teaspoonfuls of an emulsifiable spray oil in each pint.

Brief flaming of tools has not been effective in destroying the exocortis virus.

CACHEXIA (XYLOPOROSIS) (see below) was shown by Childs (16) to be a bud-transmissible virus disease which attacks stem bark and wood of several citrus species and varieties. In this country, the virus is frequently present in grapefruit and sweet orange without producing apparent symptoms, but it can cause severe symptoms on *C. macrophylla* and many varieties of mandarin, tangelo, and sweet limes. There is no evidence that the disease is carried through seed, and insect transmission has not yet been demonstrated.

The wood shows elongated pits and bark growth ridges that correspondingly

Below: Cachexia (Xyloporosis) in young Wekiwa tangelo on rough lemon rootstock.



fit into the pits. Brown, gummy deposits form in the pits and bark phloem, and the stem wood eventually becomes brown. Bark scaling, which may not be due only to cachexia, entrance of secondary organisms, and various nutritional deficiencies complete the degeneration of the tree. Many investigators are of the opinion that cachexia and xyloporosis are caused by the same virus or strains of the same virus. The disease is very important in Israel on the Palestine sweet lime scions and rootstocks in which it produces a weakened, elastic wood (44). Affected trees there are treated by inarching with sour orange.

Control is a matter of prevention—that is, the use of budwood from parent trees free of the virus, and nonsusceptible scions and rootstocks. These trees and rootstocks are found by indexing into susceptible indicator varieties, such as Orlando tangelo and Parsons Special mandarin, a method that requires waiting 2 or more years for the development of typical symptoms.

Present in several Mediterranean countries is a severe cachexia-like disease, named *cristacortis* by Vogel and Bové (48) that causes stem pitting of sour orange, Tarocco orange, Orlando tangelo, and some other varieties.

GUMMING CAUSED BY PHYSICAL AND CHEMICAL INJURIES

Grasshoppers, katydids, fire ants, and probably other insects (14) feeding on the bark, cause a formation of gum at injuries. Fire ants are controlled by applying 5 per cent chlordane granules to the ground when no fruit is present at the rate of 100 pounds per acre. Red scale may induce profuse gumming by their feeding and injection of toxic materials.

Injury accompanied by gumming on trunks can be caused by spilling heater oil on soil or trees (41).

Unneutralized copper sulfate or arsenicals contacting a root or trunk bark will kill bark in vertical strips and induce gum formations. Strong concentrations of 2,4-D (10) other weed killers and fertilizers can induce gumming when brought into contact with bark of trunk or roots.

Copper deficiency causes a nutritional disease called exanthema, in which gum formation is a prominent symptom. Gum collects at or near the leaf nodes of young succulent branches, and at the angles of fruit segments. Surfaces of twigs, leaves, and fruit become infiltrated with a brown, hard gum.

The trouble is corrected by spraying the entire tree thoroughly with 1-1-100 Bordeaux mixture, or with 5-1-4-100 zinc sulfate-copper sulfate-hydrated lime. Spraying may be done just before the spring flush of growth, or at any convenient time during the year.

Mechanical injuries do not induce gumming by themselves, but they do open the way for infection by various fungi. Injuries from sunburning and freezing almost always become invaded by fungi.

Twig die-back (36) and **fruit stem die-back** (37) are usually accompanied by the internal formation of gum which occasionally is exuded onto the twig surface. The trouble may be caused by a number of agencies among which are some mineral nutrient deficiencies and excesses (e.g. copper and boron), some insect and mite injuries (red scale and red spider), fungi (*Phytophthora* spp., *Diplodia, Botrytis,* etc.) nematodes, some virus diseases, deficiency or excess of water, and any other factor so damaging the fibrous feeder roots that they cannot take up water

Black arrow on left indicates twig die-back. White arrow to right indicates drop of gum.

Fruit-stem die-back. Left, living twig subtending healthy orange;
middle and right, dead twigs and diseased oranges.

readily. These handicaps are particularly injurious to the tree during drying winds and low humidity which cause rapid transpiration and drying of the foliage. Even with adequate soil moisture, twig die-back results if soil temperature is so low that foliage transpiration exceeds rate of water uptake by roots.

Within the control of the grower are a number of practices that tend to decrease the incidence of twig die-back. He should avoid the application of spray materials when the plants are in need of water, as just before an irrigation or when their foliage is losing water rapidly, and during or following a drying wind or excessively hot period. Windbreaks lessen the severity of damage from drying north or east or southeast winds. Pretreatment of tree sites with soil disinfestants to destroy fungi and nematodes parasitic on roots will enable the young tree to become established and make a rapid growth the first year. Careful or no cultivation and adequate but not excessive applications of fertilizer and water should also be practiced.

One of the most important orchard operations in combating the onset of twig die-back which may develop into tree decline, is to maintain as nearly as possible an optimum soil moisture content. This may best be accomplished by using enough tensiometers to give a representative sampling at two soil depths throughout the orchard, and irrigating when they indicate it is necessary.

A spray of 8 to 10 ppm of 2,4-D in water applied to Valencia oranges on May 26, or to Thomson navels on February 28, or to grapefruit on June 6 reduced fruit-stem die-back 80 to 91.6 per cent (37). Losses from die-back have been of more importance in Orange County Valencias.

LITERATURE CITED

1. Allen, Ross M.
   1968. Survival time of exocortis virus on contaminated knife blades. Plant Disease Reptr. **52**:935–939.
2. Baines, R. C., L. J. Klotz, O. F. Clarke and T. A. DeWolfe.
   1948. Hot water treatment of citrus trees for eradication of citrus nematode. California Citrograph **34**(11):482, 484.
3. Benton, R. J., F. T. Bowman, Lilian Frazier and R. G. Kebby.
   1955. Stunting and scaly butt of citrus associated with *Poncirus trifoliata* rootstock. N. S. Wales Dept. Agr. Sci. Bul. **70**:1–20.
4. Birchfield, W.
   1954. The hot water treatment of nematode-infested nursery stock. Florida State Horticultural Soc. **67**:94–96.
5. Bitters, W. P.
   1952. Exocortis on trifoliate. Citrus Leaves **32**(9)14–16, 34.
6. Bitters, W. P.
   1958. A summary of the most important factors to consider in citrus rootstock selection in California. C.E.S. Dept. of Horticulture, Mimeo., 1 page.
7. Bitters, W. P., J. A. Brusca, and N. W. Dukeshire.
   1954. Effect of lemon budwood selection in transmission of exocortis. Citrus Leaves **34**(1):8–9, 34, and California Citrograph **39**:70–71, 84–85.
8. Calavan, E. C. and D. W. Christiansen.
   1958. Production of ferment gum disease in Marsh grapefruit by fungus inoculation. (Abstr.) Phytopathology **48**:391.
9. Calavan, E. C., T. A. DeWolfe, L. G. Weathers, L. J. Klotz, and D. W. Christiansen.
   1955. Treatments for the control of brown rot of citrus fruits. Citrus Leaves **35**(11)8, 9.
10. Calavan, E. C., T. A. DeWolfe, and L. J. Klotz.
    1956. Severe damage to young citrus trees from 2,4-D. Citrus Leaves **36**(1):8–9, 24.
11. Calavan, E. C., E. F. Frolich, J. B. Carpenter, C. N. Roistacher, and D. W. Christiansen.
    1964. Rapid-index methods for exorcortis of citrus. Phytopathology **54**:1359–62.

12. Calavan, E. C., and J. M. Wallace.
1954. *Hendersonula toruloidea* Nattrass on citrus in California. Phytopathology **44**:635–39.
13. Calavan, E. C. and L. G. Weathers.
1959. Transmission of a growth-retarding factor in Eureka lemon trees. In Citrus Virus Diseases (pp. 167–177). Edited by J. M. Wallace. University of California Division of Agricultural Sciences.
14. Carman, G. E., W. H. Ewart, L. R. Jeppson, L. A. Riehl, E. L. Atkins, and J. C. Ortega.
1959. Spray program for California citrus fruits. C.E.S. Dept. of Entomology Mimeo., 59 pp.
15. Carpenter, J. B., L. J. Klotz, T. A. DeWolfe, and M. P. Miller.
1959. Collapse of young citrus trees in Coachella Valley. California Citrograph **45**(1):4, 19–21.
16. Childs, J. F. L.
1952. Cachexia disease, its bud transmission and relation to xyloporosis and to tristeza. Phytopathology **45**:265–268.
17. Childs, J. F. L.
1953. An actinomycete associated with gummosis disease of grapefruit trees. Phytopathology **43**:101–103.
18. Childs, J. F. L., G. G. Norman, and J. L. Eichhorn.
1958. A color test of exocortis infection in *Poncirus trifoliata.* Phytopathology **48**:426–32.
19. Childs, J. F. L., and R. E. Johnson.
1966. Preliminary report of seed transmission of psorosis virus. Plant Disease Reptr. **50**(2):81–83.
20. Fawcett, H. S.
1931. Bark diseases of citrus in California. Cal. Agr. Ext. Bul. **395**:1–59, 19 figs.
21. Fawcett, H. S.
1936. Citrus diseases and their control. 2d ed. 656 pp. McGraw-Hill Book Co., Inc., New York, N. Y.
22. Fawcett, H. S.
1946. Chemical treatment for psorosis or scaly bark of citrus. Citrus Leaves **26**:13. Also in California Citrograph **32**:23.
23. Fawcett, H. S., and L. C. Cochran.
1944. A method of inducing bark shelling for treatment of certain diseases. Phytopathology **34**:240–244. 1 fig.
24. Fawcett, H. S., and L. J. Klotz.
1939. Infectious variegation of citrus. Phytopathology **29**:911–12.
25. Fawcett, H. S., and L. J. Klotz.
1948. Exocortis of trifoliate orange. Citrus Leaves **28**(4):8 and California Agriculture **2**(10):13.
26. Garnsey, S. M., and J. W. Jones.
1967. Mechanical transmission of exocortis virus with contaminated budding tools. Plant Disease Reptr. **51**:410–13.
27. Godfrey, G. H.
1945. A gummosis of citrus associated with wood necrosis. Science N.S. **102**:130.
28. Godfrey, G. H.
1946. An actinomycete inducing wood necrosis and gummosis in citrus. Phytopathology **36**:398.
29. Godfrey, G. H.
1946. Infectious wood necrosis and gummosis of citrus. Lower Rio Grande Valley Citrus Institute Proceedings **1**:66–70.
30. Klotz, L. J.
1955. Diseases of citrus and subtropicals and their control. C.E.S. Dept. of Plant Pathology, Mimeo., 3 pp.
31. Klotz, L. J.
1961. Color handbook of citrus diseases. 3rd ed. 75pp., 56 col. pls., 4 halftones. Univ. of California Press, Berkeley and Los Angeles.
32. Klotz, L. J., W. P. Bitters, T. A. DeWolfe, and M. J. Garber.
1967. Orchard tests of citrus rootstocks for resistance to Phytophthora. California Citrograph **53**(2):38, 55.
33. Klotz, L. J., W. P. Bitters, T. A. DeWolfe, and M. J. Garber.
1968. Some factors in resistance of citrus to *Phytophthora* ssp. Plant Disease Reptr. **52**(12): 952–955. Also, California Citrograph **54**(4):142–143.

34. KLOTZ, L. J., T. A. DEWOLFE, and M. P. MILLER.
1967. Dry root rot may be confused with brown rot gummosis. California Citrograph **52**(5):222–25.
35. KLOTZ, L. J., T. A. DEWOLFE, and R. C. BAINES.
1969. Resistance of trifoliate orange selections to gummosis. California Citrograph **54**.
36. KLOTZ, L. J., T. A. DEWOLFE, L. C. ERICKSON, L. B. BRANNAMAN, and M. J. GARBER.
1962. Twig die-back of citrus trees. California Citrograph **47**(3):74, 86, 88, 90, 91.
37. KLOTZ, L. J., and W. S. STEWART.
1948. Fruit-stem dieback. California Agriculture **2**(9):7.
38. MOREIRA, S.
1961. A quick field test for exocortis. Proc. 2nd Conf. Intern. Organization Citrus Virol. p. 40–42, W. C. Price, Ed.; Univ. Florida Press, Gainesville.
39. NAUER, E. M., E. C. CALAVAN, C. N. ROISTACHER, R. L. BLUE, and J. H. GOODALE.
1967. The citrus variety improvement program in California. California Citrograph **52**(4):133, 142–152.
40. OLSON, E. O.
1952. Investigations of citrus rootstock diseases in Texas. Rio Grande Valley Hort. Inst. Proc. **6**:28–34.
41. PARKER, E. R.
1933. Loss of oil from orchard heaters while standing. California Citrograph **18**(6):163, 184.
42. PUJOL, A. R.
1966. Difusión natural de psorosis en plantas citricas. INTA, Est. Exp. Agropecuaria Concordia, Ser. Tec. No. 8. 15p.
43. PUJOL, A. R.
1966. Transmision de psorosis a travès de la semilla de citrange Troyer. INTA, Est. Exp. Agropecuaria Concordia No. 10. 7p.
44. REICHERT, I. and J. PERLBERGER.
1934. Xyloporosis, the new citrus disease. Jewish Agency for Palestine, Agr. Exper. Sta. (Rehovot) Bul. **12**:1–50.
45. REUTHER, W., E. C. CALAVAN, E. M. NAUER, and C. N. ROISTACHER.
1968. Citrus variety improvement program provides wide benefits. California Citrograph **53**(6):205, 222–228; **53**(7):275–280.
46. ROISTACHER, C. N., R. L. BLUE, and E. C. CALAVAN.
1969. Preventing transmission of exocortis virus. California Citrograph **54**(3):91, 100–02.
47. ROUNDS, M. B.
1946. The chemical treatment of psorosis (scaly bark). California Fruit Growers Exch. Pest Control Circular. Subject Series 4.
48. VOGEL, R. and J. M. BOVE
1968. Cristacortis, a virus disease inducing stem pitting on sour orange and other citrus species. In Proc. 4th Conf. Intern. Organization Citrus Virologists, pp. 221–228. Edited by J. F. L. Childs. Univ. Florida Press, Gainesville.
49. WALLACE, J. M.
1957. Virus-strain interference in relation to symptoms of psorosis disease of citrus. Hilgardia **27**:223–246.
50. WEATHERS, L. G.
1960. The effect of host nutrition on the development of exocortis in *Poncirus trifoliata*. (Abstr.) Phytopathology **50**:87.
51. WEATHERS, L. G., F. C. GREER, JR., and M. K. HARJUNG.
1967. Transmission of exocortis virus of citrus to herbaceous plants. Plant Disease Reptr. **51**(10):868–71.

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To simplify the information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

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WARNING ON PESTICIDE RESIDUES

Recommendations for pest control are based on the best information currently available for each pesticide listed. Treatments based upon these recommendations should not leave residues that will exceed the tolerance established for any particular chemical. To avoid excessive residues, follow directions carefully with respect to dosage levels, number of applications, and minimum interval between application and harvest.

THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other properties or crops.